

Campaign

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Bank Stability Assessment Tool for Bridge and Abutment Infrastructure in Iowa (#3213)

Author:



Submitted anonymously...

🔖 Bridges & Structures

🔖 Design

🔖 Geotechnical

🔖 Hydraulics, Hydrology, & Drainage

12/18/2020 - 2:12pm | Completed

Description

Need to identify streams that show signs of erosion that threaten DOT infrastructure and develop assessment strategies to allow decision makers early signs of potential erosion problem areas.

Is this related to or a continuation of a previous Iowa DOT research project?

No

Does this idea include matching funds?

No

Anticipated Benefits

GIS model for analyzing bank erosion in and around structures.

Focus Area

Safety / Sustainability / Technology

Research Program

SPR / 774: Research & Technology Transfer

Project Title

Bank Stability Assessment Tool for Bridge and Abutment Infrastructure in Iowa

Project Number

RB10-014

Contracted Agency

Iowa Department of Natural Resources / University of Tennessee

Funding Program

State Planning and Research

Project Funding

\$160,000

Project Start Date

09/01/2014

Current Project End Date

05/30/2020

Abstract

In Iowa, bank erosion is a persistent and severe problem. Yet, the lack of field data and remote sensing imagery inhibits characterization of the spatial and temporal variability of soil strength and erodibility, which influences bank erosion mechanisms. There is a critical need for a geomorphic-geotechnical-hydraulic approach that utilizes currently available tools (e.g., LiDAR; GIS; PEEPs; recirculating flumes; numerical models) to quantify the extent of bank erosion near bridges at a suitable spatial scale and over time.

The Iowa Department of Natural Resources, Iowa Geological Survey, and the University of TennesseeKnoxville provide a multi-dimensional approach to identify and map currently eroding banks in 3rd - 6th order streams that intersect with bridge structures in Iowa. This approach includes geotechnical and hydraulic data that capture the spatial and temporal variability of the bank soil strength under changing climate, moisture and land-use conditions to provide the likelihood and severity of bank erosion.

This study substantiates spatial patterns and temporal cycles of bank erosion in the Major Land Resource Areas (MLRAs) of the state. MLRAs 107A, 107B, 108C, and 108D exhibit similar patterns due to the loess soils covering western and southern Iowa. These soils have higher average critical shear stresses than the coarser, till-derived soils in MLRAs 103 and 104 of north central and northeast Iowa. However, MLRAs 107A and 107B have Factors of Safety less than one for at least 95% of their observed flows suggesting that fluvial erosion is highly likely and thus, they have the highest density of eroding banks.

Regression models using existing databases and new GIS coverages developed during this project were established using eleven parameters including bank height, stream sinuosity, stream slope, available water capacity, clay content, and bulk density, among other parameters. Stream length to bridge length ratios were used to identify the potential threat for bridges in the near future. In addition, streambank polygons were developed and intersected with right-of-way features to identify roads that may be impacted by lateral channel migration. Bridges with a high ratio and a stream having a high potential for migration were flagged.

The greatest number of bridges threatened by stream migration were found in MLRAs 107B and 108D, followed closely by MLRAs 103 and 107A. The greatest risk to roadways were in MLRAs 107B and 103. The project identified 1,515 bridges and 281 road right-of-ways in Iowa that were considered to be at high or moderate risk of future erosion by channel migration. The study provides a means to prioritize those bridge structures across the state that need further protection from pending bank failures.

Project Complete Date

03/05/2021

Project Deliverables

[Final Report](#)

Executive Summary

In Iowa, bank erosion is a persistent and severe problem that constantly threatens the state's highways and bridge crossings. However, the lack of field data and remote sensing imagery inhibits characterization of the spatial and temporal variability of the soil strength and erodibility parameters causing bank erosion. There is a critical need for a coupled geomorphic-geotechnical-hydraulic approach that utilizes currently available tools (e.g., LiDAR; GIS; PEEPs; recirculating flumes; numerical models) to provide a quantitative, science-based, assessment of bank erosion severity near bridges at a suitable spatial scale and over time.

The Iowa Geological Survey, Iowa Department of Natural Resources, and Hydraulics & Sedimentation Lab at the University of Tennessee-Knoxville provide here an innovative, multidimensional approach that utilizes aerial LiDAR surveys to map currently eroding banks in 3rd - 6th order streams that intersect with bridges in Iowa. This approach includes geotechnical and hydraulic data that consider the spatial and temporal variability of bank soil strength under changing climate, moisture, and land-use conditions to provide projected Factors of Safety, as well as the likelihood and severity of bank erosion across Iowa.

Herein, we characterized the range of bank erosion rates in Iowa by examining existing studies. Annual recession rates ranged from -1.2 cm/yr (deposition) in central Iowa to 34.2 cm/yr in southern Iowa. The average recession rate in 3rd order streams was 12.4 ± 10.3 cm/yr. The mean recession rates increased systematically for stream orders 4 through 6 to 18.1, 31.9 and 53.8 cm/yr, respectively. These past studies, though, were limited to the reach scale. Thus, we developed a new approach for identifying severely eroding streambanks that uses the slopes between adjacent cells in a high-resolution LiDAR coverage map to characterize the relationship between streambank angles and streambank heights. The method was applied to the 3rd - 6th order streams across the state for a first-order approximation of eroding streambank lengths in Iowa. Approximately 35,200 km of the banks along 3rd to 6th order rivers in Iowa are severely eroding, which is 41% of the total streambank length in the state. This is double that of a "natural" stream, which suggests streambank erosion has been enhanced by external forcings.

With this degree of variability in soil properties, topography, weather, land-uses and hence erosion rates in Iowa, it would seem inappropriate to develop a single predictive relationship for all of the state's stream miles. We did observe some regional generalities, though, that would help minimize the number of needed relationships. This study substantiated spatial patterns and temporal cycles of bank erosion in the Major Land Resource Areas (MLRAs) of the state. MLRAs 107A, 107B, 108C, and 108D have similarities most likely due to the loess soils in western and southern Iowa. These soils have higher average critical shear stresses than the coarser till-derived soils in MLRAs 103 and 104 of north central and northeast Iowa. However, MLRAs 107A and 107B have Factors of Safety less than one for ~95% of their observed flows suggesting that fluvial erosion is likely. Thus, they have high densities of eroding banks per area.

Along with this spatial variability in soil strength and erodibility, there is temporal variability related to soil moisture and freeze-thaw cycles which weaken the soil's strength. The critical shear strength reaches minimum values during March and April when soil moisture is high and there are several freeze-thaw events. The strength peaks in August when the effects of freeze-thaw are non-existent and soil moisture is at a moderate level. Over the winter, MLRAs 103 and 107A have high critical shear stress values during the winter due primarily to low moisture content, while MLRAs 104 and 108D have high moisture content over the winter and thus lower critical shear stress values.

Regression models using existing databases and new GIS coverages developed during this project were established using eleven parameters including bank height, stream sinuosity, stream slope, available water capacity, clay content, and bulk density, among other parameters. Stream length to bridge length ratios were used to identify the potential impact for bridges in the near future. For the roadways, stream migration polygons were buffered 20 feet and intersected with right-of-way features to identify roads that may be impacted by lateral movement from streams. Bridge crossings with a high ratio and a stream having a high potential for migration were flagged.

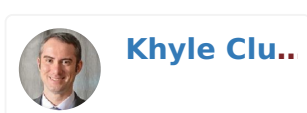
Overall, the greatest number of bridges threatened by stream migration were found in MLRA 107B and 108D, followed closely by MLRAs 103 and 107A. The greatest risk to road ROWs were also assessed in MLRA 107B and 103. All-together, the project identified 1,515 bridges and 281 road right-of-ways in Iowa that were considered to be at high or moderate risk to future erosion and channel migration.

This study produced four published peer-reviewed manuscripts (and 1 manuscript in preparation), which included an estimation of bank erosion in the state, as well as an assessment of the degree of spatial and temporal heterogeneity of bank soil strength, erodibility, and Factors of Safety for a range of flows conditions. This study also provided a LiDAR-based algorithm to identify eroding streambanks at a regional scale and regression models at the regional scale using common geomorphic and geotechnical parameters to quantify bank retreat. Geodatabases and coverage maps of severely eroding stream banks that intersects with bridge and roadway infrastructure were provided to the Iowa Department of Transportation as a means to prioritize those bridge structures across the state that need further protection from pending bank failures.

Project Champion:



Project Manager:



Task Management

No Results Found

Expert Management

No Results Found

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Comments

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